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EVALUATION OF THE VAPOR PROTECTION CAPABILITIES OF THE JACKET/TROUSER INTERFACE ON THE REGULATION GROUND-CREW CHEMICAL DEFENSE ENSEMBLE

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The voluntary fully informed consent of the subjects used in this research was obtained as required by AFR 169-3.

The Office of Public Affairs has reviewed this report, and it is releasable to the National Technical Information Service, where it will be available to the general public, including foreign nationals.

This report has been reviewed and is approved for publication.

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13. ABSTRACT *(Maximum 200 words)*
The ground-crew chemical defense ensemble (CDE) has deficiencies in its ability to prevent chemical warfare (CW) simulant vapors from leaking past the outer charcoal layer in the abdominal region when personnel wearing this CDE perform exercise in a simulant CW agent vapor. The purpose of this study was to determine the site and amount of vapor penetration. A charcoal-fabric cummerbund was used as an experimental tool to prevent vapor from leaking through the jacket/trouser interface. Test subjects, wearing the ground-crew CDE with and without cummerbund, performed exercises in a CW simulant vapor (methyl salicylate). While subjects were exposed to the simulant vapor, vapor concentrations were measured under the CDE jacket in the abdominal region. After removing the CDE in a vapor-free area, subjects entered sealed offgassing booths where simulant vapor levels were continuously measured. Subjects wearing a cummerbund had 80% lower abdominal vapor concentrations and 33% lower maximum offgassing booth concentrations than subjects that did not wear a cummerbund. The source of the vapor penetration is along the jacket/trouser interface of the ground crew CDE.

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EVALUATION OF THE VAPOR PROTECTION CAPABILITIES OF THE JACKET/TROUSER INTERFACE ON THE REGULATION GROUND-CREW CHEMICAL DEFENSE ENSEMBLE

INTRODUCTION

The function of the ground-crew chemical defense ensemble (CDE) is to protect personnel from threats posed by all forms of nerve, vesicant, and blood agents in a chemical warfare (CW) environment. A recent chemical defense study, performed at the Survivable Collective Protection Shelter (SCPS-2B) at the USAF School of Aerospace Medicine (USAFSAM), Brooks AFB, indicated that the ground-crew CDE may have deficiencies in its ability to prevent simulant vapor from penetrating into the abdominal areas when worn by personnel performing light exercise. In this study (KRUG Study No. 03-88-19, Appendix A) simulant vapor concentrations were measured in the abdominal region* between the CDE and the fatigue jacket while subjects exercised in a simulant vapor challenge area. The mean vapor level measured in the abdominal region was 17% of the outside level; thus a significant amount of simulant vapor leaked past the charcoal layer of the ensemble and posed a threat to the wearer.

Most of this vapor penetration probably occurred while the subjects were exercising, when torso movements caused the internal volume of the abdominal region to cyclically increase and decrease. The ground-crew CDE has considerable extra volume in the torso region of the jacket so that it can accommodate all of the individuals in each garment size. The bellows-like action produced by the volume changes of the excess torso material during exercise may have caused enough outside air to flow into the abdominal region to cause this vapor leak.

There are two possible routes for the vapor to get past the outer charcoal layer of the CDE jacket. The first route is by passing directly through the ventile charcoal-impregnated material from which the CDE jacket is made. For this penetration to occur, the bellowing action of the jacket must produce high air velocities through the material. The high velocities mean reduced vapor residence time in the fabric and, consequently, a reduced chance of these vapors being absorbed by the activated charcoal.

The second route of vapor entry into the abdominal region would be through channels along the jacket/trouser interface. The ground-crew CDE jacket and trousers are separate garments. The trousers are secured to the waist by two adjuster straps located on the right and left sides of the trousers. The only solid connection between the jacket and trousers is at the back, where three

*Throughout the remainder of this report "Abdominal region" refers to the air space between the CDE and fatigue jacket that is located between the waist and the chest.

snap fasteners connect the two garments. The remainder of the vapor seal at the jacket/trouser interface is created by an elastic waist cord that runs through a seam in the bottom of the jacket. During donning, this elastic cord is stretched and tied in a butterfly bow knot and positioned so that it overlaps the top of the trousers, which creates the vapor seal. But, even when properly donned, a visual inspection of the front of the jacket/trouser interface reveals a number of potential air channels between the external environment and the abdominal region because of bunching of the jacket seam.

The purpose of this study was to quantitate the amount of simulant vapor that penetrates into the abdominal region and determine whether this vapor was leaking through openings along the jacket/trouser interface, or whether it was being convected through the charcoal-impregnated fabric without being absorbed by the charcoal. Study subjects wore the ground-crew CDE with and without a charcoal fabric cummerbund. The cummerbund was made of a ventile fabric and was an experimental tool intended to cover the jacket/trouser interface and prevent leaks through this interface, but still allow air to pass through the ventile charcoal fabric of the ensemble.

This study was conducted on 14-17 Nov and 12-15 Dec 1988 at the USAFSAM/VNC Chemical Defense Facility (Bldg 1192). Methyl salicylate (MeS) was used as the CW agent simulant. Subjects performed light exercise in an MeS vapor challenge area while vapor levels in the abdominal region were being measured with Tenax tubes. After the vapor exposure, subjects doffed their CDEs in a vapor-free open area, then entered sealed offgassing booths where the simulant vapor levels were continuously measured. The effectiveness of the cummerbund in preventing vapor penetration into the abdominal region was determined by comparing the Tenax tube concentrations and the offgassing booth concentrations for the subjects that did and did not wear a cummerbund.

EQUIPMENT

Ground-Crew CDE

Table 1 gives the complete list of the items in the ground-crew CDE. All items were worn in standard fashion, except for the hood skirt, which was always worn tucked under the CDE jacket. A previous study(1) had shown that a significant amount of vapor penetrates under the hood skirt when it is worn outside the CDE jacket. To accurately quantitate the leakage at the waist, the leakage under the hood skirt was minimized by always wearing the hood skirt tucked under the CDE jacket, as shown in Figure 1.

Charcoal Fabric Cummerbund

The cummerbund was constructed of ventile, charcoal-impregnated material obtained from chemical casualty bags (NSN 8465-01-079-9875). These casualty bags had been recently removed from service because their 5-year shelf life had expired. Elastic bands secured with Velcro tabs were used to hold the cummerbund tightly in place around the subject's waist. To don the cummerbund, it was loosely placed around the waist, then the excess CDE jacket material was lifted upward away from the waist area. The excess torso fabric of the CDE jacket was draped over the top of the cummerbund, and then the cummerbund was tightly secured around the waist. Removing the excess fabric underneath the cummerbund created a smooth cylindrical surface at the

TABLE 1. ITEMS IN THE GROUND-CREW ENSEMBLE

Battle Dress Overgarment (OG-84) -- (Jacket and Trousers)
Trousers, Cotton, Fatigue
Coat, Cotton, Fatigue
Underwear, T-Shirt-White
Socks, Tube, Men's White
Boots, Combat
Overboot, Chemical Protection (CP)
Gloves, Set, CP, Ground-crews
Gloves, Insert, White Cotton Knit
M17 Mask
N 16A-2 Hood, CP

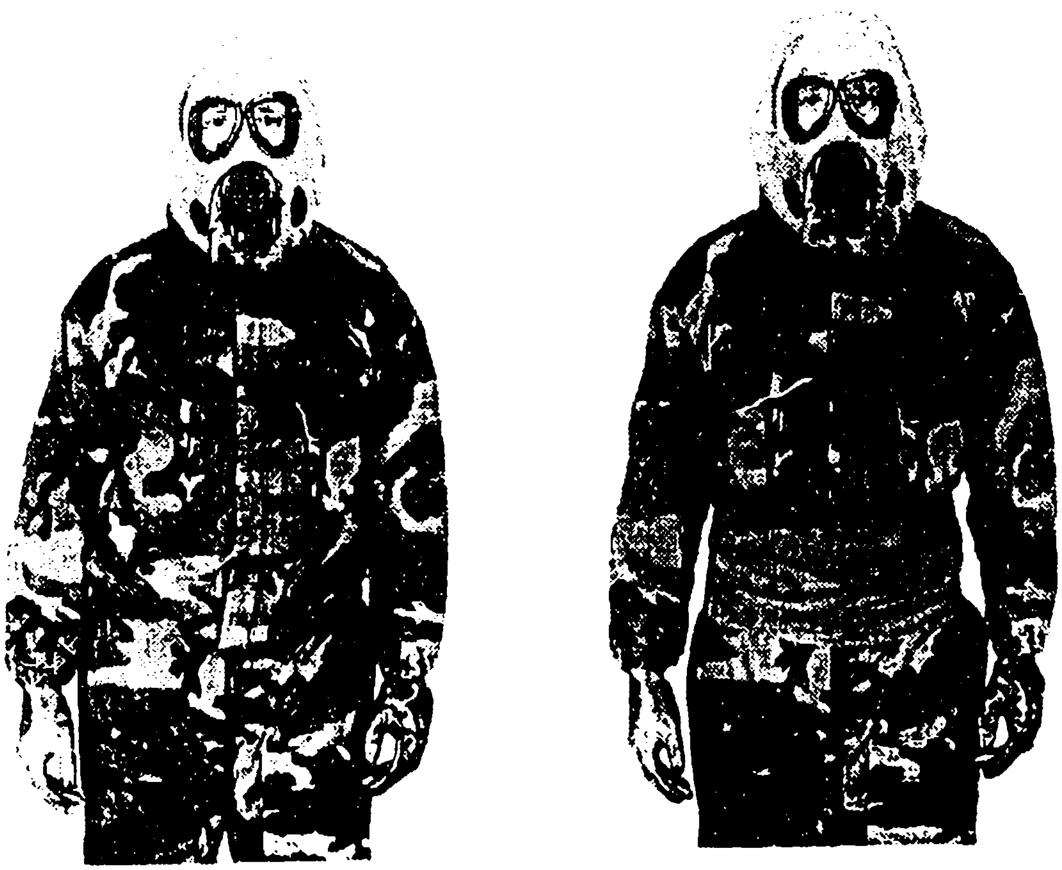

Figure 1. Subject wearing the regulation ground-crew CDE with the hood skirt tucked under the CDE jacket (left side). Same CDE with the charcoal fabric cummerbund wrapped around the jacket/trouser interface (right side).

intersection of the CDE jacket and trousers, which prevented overlapping jacket material from forming air channels underneath the cummerbund.

Subject Information

The pertinent data for the 4 subjects that participated in the study are given in Table 2.

TABLE 2. SUBJECT DATA

Subject No.	Age	Sex	Height (in.)	Weight (lb)
1	23	M	68.25	147
2	28	M	74.0	178
3	21	M	67.0	150
4	30	M	69.0	145

Test Facility

This study used the full-scale mockup of the SCPS-2B facility constructed by the Chemical Defense Branch, USAF School of Aerospace Medicine. The floor plan and general layout of this test facility are shown in Figure 2, along with the SCPS-M and the Transportable Shelter (SCPS-3) liquid hazard area (LHA).

For the purposes of this study, sequential impinger samplers were installed in the SCPS-3 LHA, the toxic free area (TFA) of the SCPS-2B and the TFA offgassing booths to provide continuous sampling of local levels of MeS vapor. The location and identification references of these vapor samplers are shown in Figure 2. A detailed description of the sequential impinger system can be found in the Conkle et al. report(2). The cycle time for all pumps in the SCPS-2B (S8, S11, S12, S13, S14) was 30 min. The cycle time for the impinger pump in the SCPS-3 LHA (S20) was 5 min. The impinger pump flows were checked before use on each day of the study.

Tenax Tube Details

Vapor levels in the abdominal area were measured with Tenax tubes that were attached to an elastic band that encircled the lower rib cage. Figure 3 shows the tube positioning around the chest and at the center of the back with the sampling end pointed downward. Vapors are transported by diffusion through the tube to the Tenax material inside, which absorbs the vapors. Vapor sampling is started by removing the cap on the sampling end of the tube and terminated by recapping the tube. A detailed description of the methods used to extract the MeS from the Tenax material and calculate the local vapor concentration can be found in the Brown et al. report(3).

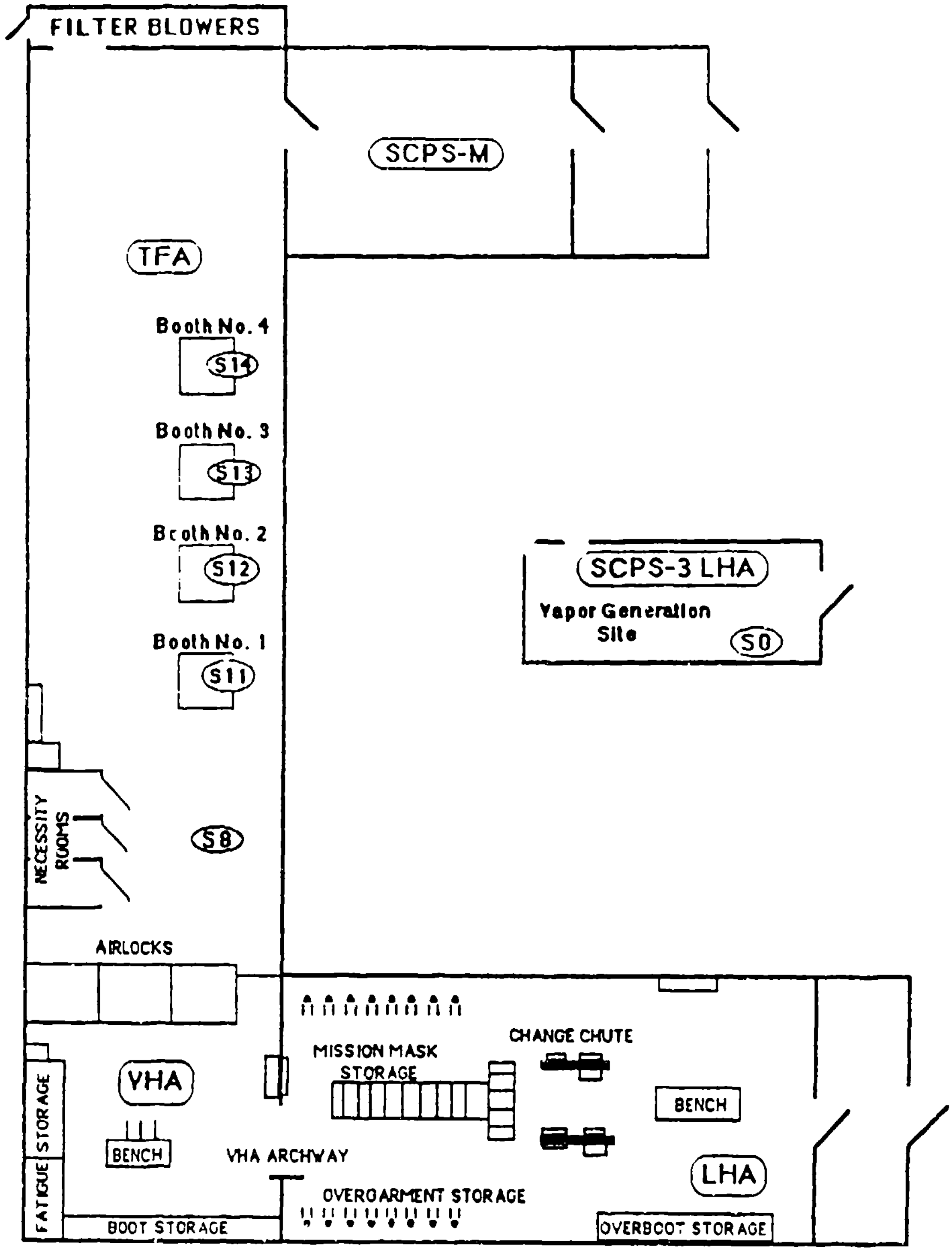

Figure 2. Schematic of SCPS-2B, SCPS-3 LHA, and SCPS-M showing the sites (S#) where the sequential impinger samplers are located. The SCPS-3 LHA was used as the vapor challenge area.

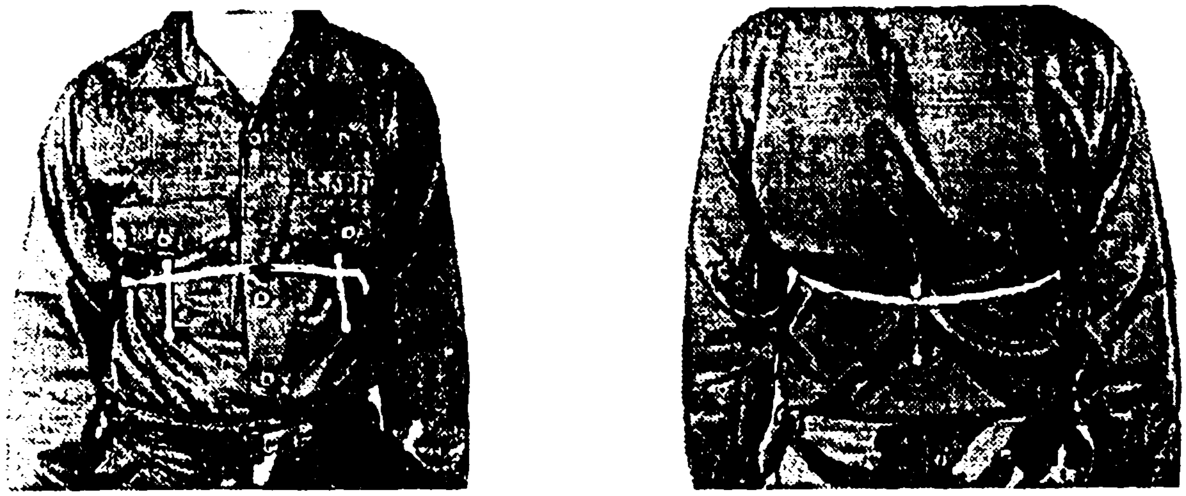

Figure 3. Positioning of Tenax tubes in the abdominal area between the fatigue and CDE jacket.

PROCEDURES

Subjects entered the offgassing booths at approximately 8:00 a.m. on each test day for the measurement of baseline levels of MeS. Subjects wore clean long underwear and socks into the booths, the same clothing that they would wear back into the booths after the experimental exposure to the simulant vapor. The baseline vapor measurements were made for 1 h (2 offgassing booth impinger cycles).

After the baseline measurements were complete, subjects donned their CDEs in the High Bay area of Bldg 1192. New ground-crew CDEs were worn on each day of the study. Table 3 lists the subjects that did and did not wear a cummerbund on each day of the study. Military personnel from Bldg 1192 assisted and inspected the subjects during the donning procedure. The assistants made sure that the test subjects tightly secured the waist draw cord on the CDE jacket and, if a cummerbund was worn, that any excess jacket material did not remain under the cummerbund, but was drawn over the top of the cummerbund (See Fig. 1). The caps on the Tenax tubes were removed just before each subject entered the vapor challenge area.

TABLE 3. ENSEMBLE TYPE WORN BY SUBJECT

Day	Subject No. 1	2	3	4
1,5	W	W	W/O	W/O
2,6	W	W/O	W/O	W
3,7	W/O	W/O	W	W
4,8	W/O	W	W	W/O

W/O = Regulation ground-crew CDE without charcoal fabric cummerbund

W = Regulation ground-crew CDE with a charcoal fabric cummerbund

An MeS vapor challenge of approximately 25 mg/m^3 was generated in the vapor challenge area, the LHA of the SCPS-3, by evaporating MeS from a 50 ml pot, inserted in a heating mantle. A 50-volt potential to the heating mantle created the vapor challenge 10 min before the first subject entered the vapor challenge area. When the first subject entered the vapor challenge area, the heating mantle voltage was reduced to 25 volts, a voltage that produced an evaporation rate which maintained a relatively constant vapor level.

Subjects entered the vapor challenge area at 5-min intervals and remained there for 20 min. The subjects' daily entry times are given in Table 4. The reference time (0 min) is the time that the impinger pumps at sites S20 and S8 were simultaneously started, usually about 9:15 a.m. The daily entry and exit times coincide with the 5-min sampler cycle at position S20, so that each subject's daily exposure level could be accurately determined.

TABLE 4. SUBJECT ENTRY TIMES (MIN) INTO THE VAPOR CHALLENGE AREA

Day	Subject No. 1	2	3	4
1,5	5	10	15	20
2,6	20	5	10	15
3,7	15	20	5	10
4,8	10	15	20	5

While the subjects were in the vapor challenge area, they repeated the set of exercises given in Table 5 every 5 min. This exercise set was intended to simulate movements that ground crew would perform while servicing an aircraft: reaching above the head, bending at the waist, and walking.

TABLE 5. FIVE-MINUTE EXERCISE SET PERFORMED IN VAPOR CHALLENGE

Period Time (min)	Exercise	Frequency
0:00 - 0:30	Stand still	-
0:30 - 2:00	March in place	1 step/s
2:00 - 3:30	Extend arms up	1 ext/5 s
3:30 - 4:30	Touch toes	1 toe touch/5 s
4:30 - 5:00	Stand still	-

After exiting the vapor challenge area, each subject remained in the High Bay area, where he removed his boots, CDE, and fatigues as quickly as possible. The Tenax tubes were removed and capped by an attendant as soon as the CDE jacket was opened. Once all required clothing was removed (subjects were still wearing their T-shirts, long underwear, and socks), the subjects walked through the SCPS-M to the SCPS-2B TFA and, after starting the impinger pump for their booth, entered their booth. Subjects remained in the booths for 1.5 h (3 offgassing booth impinger cycles). Subjects were assigned booths according to their Subject No. (Booth 1 - Subject 1, etc.), and each subject used the same booth on each day of the study. The inside of each booth was cleaned with alcohol at the end of each day.

RESULTS

The background vapor levels represent the amount of MeS vapor offgassed by the subject, his underwear and socks, and the offgassing booth before any experimentally induced contamination. The daily measured background levels for each subject/booth combination are given in Table 6.

TABLE 6. BACKGROUND VAPOR LEVELS OF METHYL SALICYLATE (mg/m^3)

Subject No.	Day 1	2	3	4	5	6	7	8
1	.005	.005	.003	.006	.001	.005	.005	.004
2	.004	.003	.002	.004	.002	.003	.003	.003
3	.004	.003	.004	.005	.001	.005	.003	.005
4	.004	.002	.003	.004	.001	.006	.003	.004

The mean challenge vapor concentration (mg/m^3) to which each subject was exposed during the 20-min period in the SCPS-3 LHA (vapor exposure area) is listed in Table 7. Each daily concentration is the mean concentration of the four 5-min impinger cycles during the time the subject remained in the vapor challenge on that day. The daily levels fluctuated considerably, even though the same basic technique was used to generate the vapors. This fluctuation may reflect the fact that the vapor buildup period, the time the 50-volt potential was applied to the heating mantle, was not rigidly adhered to (i.e., it varied from approximately 8 to 12 min) because of subject preparation requirements.

TABLE 7. MEAN CHALLENGE VAPOR CONCENTRATION (mg/m^3)

Subject No.	Day 1	2	3	4	5	6	7	8
1	16.7*	41.1*	19.5	27.4	13.3*	29.6*	33.2	33.1
2	20.8*	36.7	17.3	27.8*	15.4*	42.6	23.8	34.2*
3	22.9	45.2	22.2*	24.6*	15.4	42.5	39.0*	31.8*
4	22.0	45.4*	22.3*	22.8	13.4	35.7*	40.9*	26.4

*Subject wore charcoal fabric cummerbund.
Mean exposure for subjects wearing the ground-crew CDE without a cummerbund = 27.8 $\pm$ 10 mg/m^3
Mean exposure for subjects wearing the ground-crew CDE with a cummerbund = 28.8 $\pm$ 10 mg/m^3

The MeS vapor concentrations measured with the Tenax tubes in the abdominal region are listed in Table 8. The concentrations in Table 8 are normalized with respect to the outside challenge concentration, i.e., each concentration is expressed as a percentage of the daily challenge concentration (Table 7). The abdominal concentration used to calculate the normalized concentration in Table 8 is the mean concentration of the 3 Tenax tubes on the subject. The daily concentrations measured at the individual sites in the abdominal region are given in Table B-1 of Appendix B.

TABLE 8. NORMALIZED SIMULANT VAPOR CONCENTRATIONS IN THE ABDOMINAL REGION (%)

Subject No.	Day 1	2	3	4	5	6	7	8	Subject Means
1	4.9*	1.0*	5.3	3.9	0.0*	0.0*	11.1	5.7	4.0
2	2.7*	8.1	14.0	.3*	.2*	10.4	7.8	0.0*	5.4
3	4.4	6.2	2.3*	.7*	3.1	4.3	1.4*	.7*	2.9
4	4.3	1.1*	1.5*	4.3	8.0	.4*	0.0*	4.8	3.0

* Subject wore charcoal fabric cummerbund.
Mean abdominal vapor levels for subjects in ground-crew CDE w/o cummerbund = 6.61% + 3.08%
Mean abdominal vapor levels for subjects in ground-crew CDE with cummerbund = 1.08% $\pm$ 1.30%

The maximal offgassing booth concentrations (MBC) are listed in Table 9. The background vapor levels (Table 6) were subtracted from the original data to obtain these concentrations.

TABLE 9. MAXIMAL OFFGASSING BOOTH VAPOR CONCENTRATION (mg m^{-3})

Day	1	2	3	4
1	.006*	.004*	.005	.004
2	.006*	.005	.010	.008*
3	.004	.005	.003*	.003*
4	.007	.003*	.007*	.006
5	.003*	.002*	.005	.009
6	.007*	.009	.018+	.002*
7	.009	.008	.007*	.009*
8	.005	.002*	.005*	.006
Subject Mean	.0059	.0048	.0075	.0059

Mean MBC for subjects who wore ground-crew CDE without cummerbund $= .0072 \pm .0035$ mg m^{-3}

Mean MBC for subjects who wore ground-crew CDE with cummerbund $= .0048 \pm .0023$ mg m^{-3}

*Subject wore charcoal fabric cummerbund

+Waist cord came undone during the exercise period

DISCUSSION

There was significant penetration of simulant vapors into the abdominal region of subjects who wore the ground-crew CDE without a cummerbund. The mean normalized abdominal vapor concentration was 6.61% of the outside concentration (Table 8). This data confirm the finding of the previous study (KRUG Study No. 03-88-19), although the mean normalized concentration measured in the previous study (17%) was much greater. Apparently, abdominal concentrations were lower in this study because subjects were specifically instructed to tightly tie the waist cord, whereas in the previous study they donned the CDE without specific instructions concerning the waist cord.

The mean abdominal vapor concentration measured in the front was higher than the concentration measured in the back area (see Table B-1) of the subjects that did not wear a cummerbund. The back area had a mean simulant vapor concentration of .76 mg/m^3, while the mean concentration at the 2 front positions was 2.41 mg/m^3 (see Table B-1). There was no difference between the mean concentration measured with tubes located at the right front (PR) and left front position (PB).

When the subjects wore the cummerbund, the mean normalized abdominal vapor concentration was 1.08%, an 84% reduction compared to when the cummerbund was not worn. The challenge level for the 2 test groups, subjects with and without a cummerbund, was similar (see Table 7). Based on a 2-way analysis of variance, with subsampling, this reduction in abdominal concentration is statistically significant (P - value = 0.03).

Figure 4 shows the daily mean challenge concentration vs. the abdominal concentration for subjects wearing the CDE with and without a cummerbund. When a cummerbund was worn, there was no relationship between the abdominal concentration and the challenge concentration, an indication that no leak was present. When a cummerbund was not worn, the magnitude of the abdominal concentration was directly dependent on the magnitude of the external challenge concentration. This positive correlation could only exist if a leak between the abdominal region and the external environment was present. The linearity of this relationship indicates that the leakage of air into the abdominal region was relatively constant for all of the subjects that did not wear a cummerbund.

Since the cummerbund did significantly reduce the abdominal vapor levels, the vapor entering the abdominal region of subjects without cummerbund had entered through air channels in the jacket/trouser interface. On subjects with a cummerbund, the cummerbund blocked this flow or presented enough charcoal surface area to absorb most of the MeS vapors before the air reached the abdominal region. The cummerbund is made of a ventile fabric and it covers only a small proportion of the jacket surface. If convection through the jacket material had been the transport mechanism for the vapors found in the abdominal area of subjects without a cummerbund, then the cummerbund would not have reduced the abdominal vapor levels significantly.

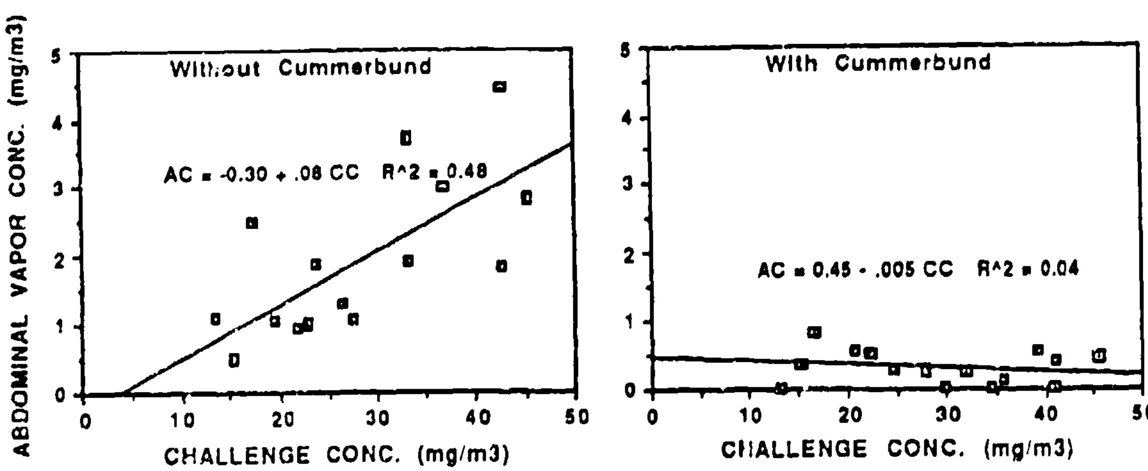

Figure 4. Mean challenge concentration (CC) vs. the abdominal concentration (AC) on each day of the study for subjects without and with a cummerbund.

The mean MBC for subjects without a cummerbund (.0072 mg/m^3) was reduced by 33.3% when a cummerbund was worn (.0048 mg/m^3). Based on a 2-way analysis of variance with replication, this reduction in MBCs is statistically significant (P - value = 0.03). The reduced offgassing booth concentrations for subjects wearing a cummerbund indicates that the leakage at the jacket/trouser interface significantly contributes to vapor carry-through into the TFA of a collective protection shelter.

Figure 5 shows the subjects' MBC plotted against their mean challenge concentrations when wearing the ground-crew CDE with and without a cummerbund. The greatest MBC of .018 mg/m^3 was produced by Subject 3 on Day 6 (without cummerbund), when the waist cord on his jacket inadvertently came undone at some time during his 20-min exercise period. With both ensembles, there was an indication of a linear relationship between the challenge concentration and the MBC.

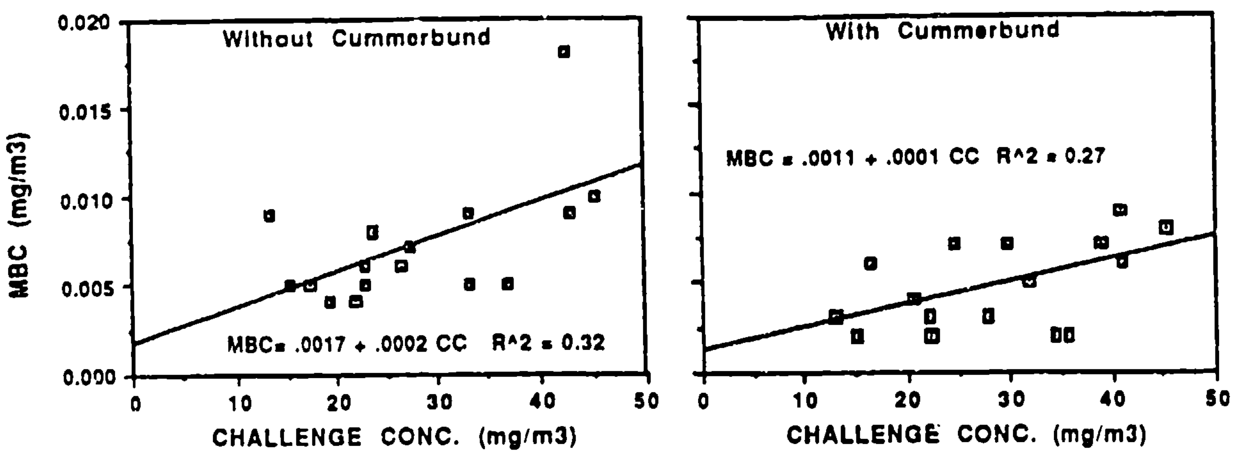

Figure 5. Maximum booth concentrations (MBC) vs. the mean challenge concentration (CC) for subjects wearing the ground-crew CDE with and without a cummerbund.

Figure 6 shows the subjects' MBC plotted against the abdominal vapor concentrations. The correlation between the MBC and the abdominal concentrations is poor. For example, on the 4 subjects where the Tenax tubes detected no vapors (concentration = 0.0 mg m^{-3}) in the abdominal region, the MBC ranges from .004 to .010 mg/m^3. On Day 6, when Subject 3 registered an MBC of .018 mg/m^3, the highest MBC of the study, the Tenax tubes recorded a relatively modest abdominal vapor concentration of 1.82 mg/m^3, or 4.3% of the outside concentration. The poor correlation between the MBC and abdominal vapor concentration indicates that the MBC depends on vapors offgassing from other parts of the body, as well as the abdominal region.

CONCLUSIONS

The results of this study show that when light exercises are performed by a person wearing the ground-crew CDE, there is considerable leakage of vapors through the jacket/trousers interface into the abdominal region. This leakage not only creates a hazard to the individual wearing the CDE, but, since it

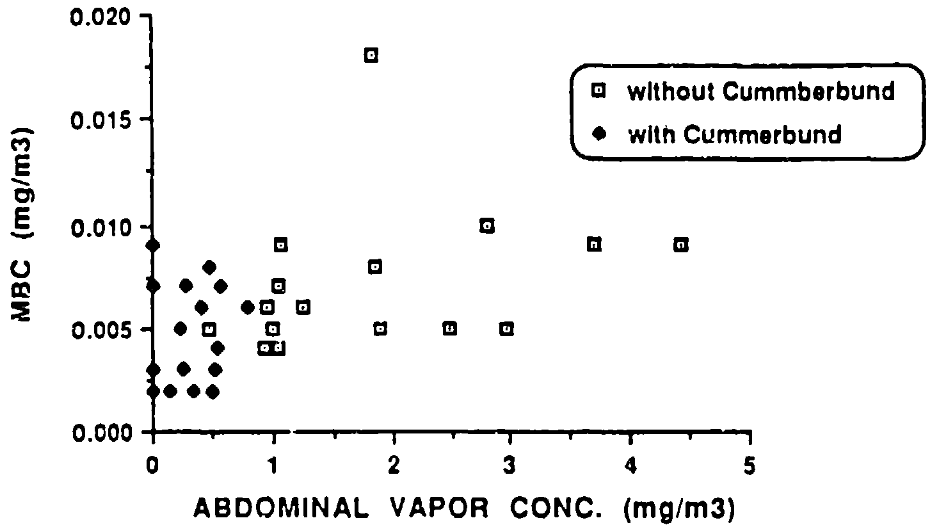

Figure 6. Mean Tenax tube concentrations vs. the maximum booth concentrations for subjects in the ground-crew CDE with and without cummerbund.

also increases vapor carry-through into a collective protection shelter, it may put other personnel at risk in the shelter. The long-term solution to the leakage at the jacket/trouser interface is a redesign of the ground-crew CDE. In the meantime, it must be stressed in training programs that the waist cord on the CDE jacket be tightly tied. In this study, subjects without a cummerbund were instructed to tightly secure the waist cord and this resulted in a 70% drop in the mean normalized abdominal concentration compared to a previous study (KRUG Study No. 18) in which subjects were not given specific instructions to tightly tie their waist cords.

Future Studies

As a follow-up to this study, it would be worthwhile to quantitate more accurately the effectiveness of the jacket waist cord tightness in controlling the amount of vapor penetration through the jacket/trousers interface. This study could use the same basic procedures as those presented in this report and the independent variable would be the degree of tightness of the waist cord: loose vs. tight.

The oversizing of the jackets on the ground-crew CDE, and the resulting, bellows action that occurs during exercise, probably causes the convection that carries the vapors through the jacket/trouser interface. A study needs to be done to see the effect of garment sizing on this bellows action. Again, the future study could follow the same format as this study, and the independent variable would be garment fit; a large vs. a custom fit CDE garment. A reduction in the CDEs bellows action may affect the cooling properties, so physiological measures of thermal stress should be measured as well.

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APPENDIX A

CHEMICAL DEFENSE FACILITY STUDY NO. 03-88-19

30 June 1988

USAFSAM/VNC (Dr Luskus)
Brooks AFB, TX 78235-5301

Subject: Outline Procedures and Test Results of USAFSAM/VNC Chemical Defense Facility Study No. 03-88-19 Conducted 30-31 March 88; 12 Apr 88; 3-5 May 88; 9-10 May 88

Study: Simulant Vapor Concentrations under the ground crew CD Ensemble (CDE).

Facility Used: USAFSAM/VNC SCPS 3 LHA

No. of Test Subjects: 2

Procedure: Two test subjects wearing the ground-crew CDE with two different configurations, standard and with hood skirt tucked in (zipper taped over), entered the SCPS-3 LHA which contained a simulant vapor challenge (methyl salicylate) of approximately 25 mg/m^3. The vapor was generated by evaporating 400 ml of methyl salicylate in two heated pots.

In the vapor challenge area the subjects performed the following set of exercises every 5 minutes.

Time	Exercise
0-1 min	walk in place
1-2 min	extend arms straight up
2-3 min	touch toes
4-5 min	stand still

Vapor concentrations in the vapor challenge area CDE were measured with Tenax tubes and impinger tubes. Vapor concentrations under the CDE were measured with Tenax tubes. Tubes were uncapped just before the subjects entered the vapor challenge area and were capped in the open air outside of the Bldg 1192 immediately after the subjects left the vapor challenge area.

Subjects remained in the vapor challenge for 20 minutes and performed four cycles of the exercise regimen.

The following table lists the locations at which vapor concentrations were measured under the CDE, the mean concentration at the site (as a % of the outside concentration) and the standard deviation and n, the number of measurements at each site.

Location	% Of Outside Concentration
Chest (on fatigue chest pockets)	4.82% $\pm$ 2.10% (n = 15)
Hips (fatigue pant pockets)	1.25% $\pm$ .5% (n = 8)
Neck Area (on fatigue collar)	
Standard Configuration (skirt out)	28.10% $\pm$ 13.78% (n = 12)
Hood Skirt Tucked In	2.41% $\pm$ .83% (n = 12)
Stomach (near solar plexus)	17.51% $\pm$ 12.12% (n =15)
Lower Back (above waist)	2.90% $\pm$ 2.17% (n = 16)
Forearm	3.57% $\pm$ 2.79% (n = 12)
Calf	2.73% $\pm$ 1.55% (n = 8)

Observations and Conclusions: In the standard CDE configuration there was extensive vapor penetration below the butyl hood and in the stomach area. The skin Ct in the neck averaged 140 mg min m^{-3}. Tucking the skirt of the hood under the CDE jacket reduced the vapor levels at the neck by 91.4%.

Vapor penetration in the stomach area appears to be due to gaps between the jacket and trouser overlap. The excess volume of material in the jacket in the stomach area makes the jacket act as a bellows type pump when the subject stretches upward or bends at the waist. Improved sizing and a better design of the waist/jacket intersection may be needed to reduce the vapor penetration in this area.

Mike Scott
Research Engineer

APPENDIX B

VAPOR LEVELS IN THE ABDOMINAL REGION

TABLE B-1. VAPOR LEVELS (mg/m^3) IN THE ABDOMINAL REGION

Subject	Day 1			Day 2			Day 3		
	P_L	P_R	PB	P_L	P_R	P_B	P_L	P_R	P_B
1	1.63*	.51*	.29*	.40*	.35*	.47*	.36	2.76	0.00
2	.36*	.54*	.76*	2.72	4.96	1.20	5.12	1.84	.33
3	.69	1.51	.80	2.18	1.13	5.12	.71*	.31*	.54*
4	1.06	1.06	.71	.45*	.34*	.67*	0.00	.38*	.64*

Subject	Day 4			Day 5			Day 6		
	PL	P_R	P_B	P_L	P_R	P_B	P_L	P_R	P_B
1	1.17	.76	.71	0.00*	0.00*	0.00*	0.00*	0.00*	0.00*
2	0.00*	0.00*	.25*	.11*	0.00*	0.00*	0.00	0.00	0.00
3	.35*	0.00*	.20*	.39	.61	.45	3.39	1.64	.43
4	.81	1.63	.48	.36	2.25	.61	.39*	0*	0.00*

Subject	Day 7			Day 8		
	P_L	P_R	P_B	P_L	P_R	P_B
1	5.48	5.05	.53	1.74	3.45	.48
2	1.58	3.97	0.00	0.00*	0.00*	0.00*
3	.45*	0.00*	1.24*	0.00*	0.00*	.66*
4	0.00*	0.00*	0.00*	1.48	1.96	.35

P_L - Tenax tube located under left breast
P_R - Tenax tube located under right breast
P_B - Tenax tube at center of back

TABLE B-2. MEANS $\pm$ S.D. OF ABDOMINAL CONCENTRATION (mg/m^3) AT EACH TENAX TUBE LOCATION

Location	Without Cummerbund	With Cummerbund
P_L	2.13 $\pm$ 1.75	.30 $\pm$ .42
P_R	2.68 $\pm$ 2.04	.15 $\pm$ .21
P_B	.76 $\pm$ 1.20	.36 $\pm$ .37